

The Impact of Human Recreational Activities in Marine Protected Areas: What Lessons Should Be Learnt in the Mediterranean Sea?

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Abstract. The aesthetic appeal of marine reserves and the facilities provided, together with the increased public awareness of nature, all contribute to creating massive tourism in MPAs. Human activities are being changed inside MPAs in two ways: humans as top predators are generally being removed, but in turn they could come back at great numbers as visitors.

Many authors have studied the impact of visitors, and the results highlight that the consequences can be very substantial and may represent a severe threat to the overall diversity of marine communities. To date, the documented effects of human recreational activities on natural communities are restricted to assessing the consequences of trampling over intertidal and upper infralittoral areas, boat anchoring in seagrass meadows and tropical reefs, or SCUBA-diving.

In this paper we review the available literature world-wide on the effects of human recreational activities in marine communities. The objective is to address the extent of these impacts and to highlight the gaps of knowledge to be filled in order to optimise decision making on research, monitoring, and management of Mediterranean MPAs. A specific plan for managing tourism use in each Mediterranean MPA should be designated. These strategies should be implemented through education, training, and changes in legislation and policy.

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Problem

For decades the creation of marine reserves has been considered the only means to restore natural communities and protect marine ecosystems. Marine protected areas (MPAs) are now being established around the world at a rapid rate (Ballantine, 1995), while 'marine-based' tourism is growing even faster (Davis & Tisdell, 1995). The aesthetic appeal of reserves and the facilities provided, together with the increased public awareness of nature, all contribute to creating massive tourism in MPAs (Badalamenti *et al.*, 2000).

When compared with the effect of fishing prohibition within no-take areas (Bell, 1983; Polunin & Roberts, 1993; Harmelin *et al.*, 1995; Russ & Alcala, 1996) and the indirect consequences of this (i.e. trophic cascades) (McClanahan & Kaunda Arara, 1996; Sala *et al.*, 1998; Pinnegar *et al.*, 2000), human frequentation may be seen as a minor component in the potential disturbance within MPAs.

To date, the documented effects of human recreational activities on marine communities are restricted to the study of the consequences of trampling over intertidal and upper infralittoral areas (Brosnan & Crumrine, 1994; Keough & Quinn, 1998; Schiel & Taylor, 1999; Eckrich & Holmquist, 2000), boat anchoring in seagrass meadows and tropical reefs (Walker *et al.*, 1989; Francour *et al.*, 1999; Creed & Amado Filho, 1999), and SCUBA-diving (Hawkins & Roberts, 1992; Sala *et al.*, 1996; Harriot *et al.*, 1997).

Human activities within MPAs are changing in two ways: humans as top predators are generally being removed (see review by Pinnegar *et al.*, 2000), but return in great numbers as visitors (see review by Badalamenti *et al.*, 2000).

The study of visitor impact on MPAs has interested a number of authors and the results highlight how substantial these effects can be, potentially threatening the diversity of marine communities (Brown & Taylor, 1999).

Physical injury to, or the removal of, a certain species or set of organisms (e.g. marine algae, seagrasses, sea fans) by trampling, SCUBA-diving or anchoring may affect not only an individual population but also, through direct and indirect effects, overall community structure and even the features of the seascape (Brosnan & Crumrine, 1994; Eckrich & Holmquist, 2000).

Most of these general patterns have been elucidated both in tropical (i.e. Creed & Amado Filho, 1999; Eckrich & Holmquist, 2000) and in non-Mediterranean temperate seas (i.e. Schiel & Taylor, 1999; Backhurst & Cole, 2000). In some cases, the increased popularity of human recreational activities in the marine environment has enhanced the number of studies within MPAs. On the other hand, very few papers have been published on the Mediterranean. The young age of Mediterranean MPAs (Badalamenti *et al.*, 2000) has probably been a major constraint in the reliable study of these aspects.

In this paper we review the available literature world-wide on the effects of human recreational activities on marine communities, with the objective of addressing the extent of these impacts and highlighting the gaps of knowledge to be filled in order to optimise decision-making on research, monitoring, and management of Mediterranean MPAs.

Discussion

Biological impacts of anchoring on seagrass meadows and tropical reefs

When intensive and unregulated, boat anchoring has been proven to be a severe threat to seagrass meadow conservation and tropical reef health (Davis, 1977; Hunnam, 1987; Creed & Amado Filho, 1999) (Fig. 1). The number of boats and their sizes, weather conditions, and substrate firmness may all affect the extent of anchor damage (Walker *et al.*, 1989; Francour *et al.*, 1999).

Despite great direct evidence, only poor documentation is available on the effects of boat anchoring on coral reefs. The detrimental consequences of this activity were initially highlighted in a study carried out in Fort Jefferson National Monument (Florida), where as much as 20 % of the reef was injured by anchoring (Davis, 1977).

More literature is available on the impact of anchoring on seagrass beds. In Western Australia, the amount of seagrass loss due to anchoring was very high and strongly related to the diverse typology of anchors (Walker *et al.*, 1989). Those results were later confirmed via long-term monitoring by aerial photographs (Hastings *et al.*, 1995).

More recently the effects of anchoring on the macroflora associated with *Halodule wrightii* have been evaluated through a field experiment carried out in a Brazilian MPA (Creed & Amado Filho, 1999). The analysis of long term effects on seagrass and macroflora highlighted that the recovery patterns may be related to both season and species.

Anchoring may also adversely affect sessile invertebrates and this may change both trophic and structural relationships in the benthic environment (Backhurst & Cole, 2000).

In the Mediterranean Sea, the main assemblages that may be potentially affected by boat anchoring are the 'coralligenous' (*sensu* Pérès, 1982), the seagrass beds (i.e.

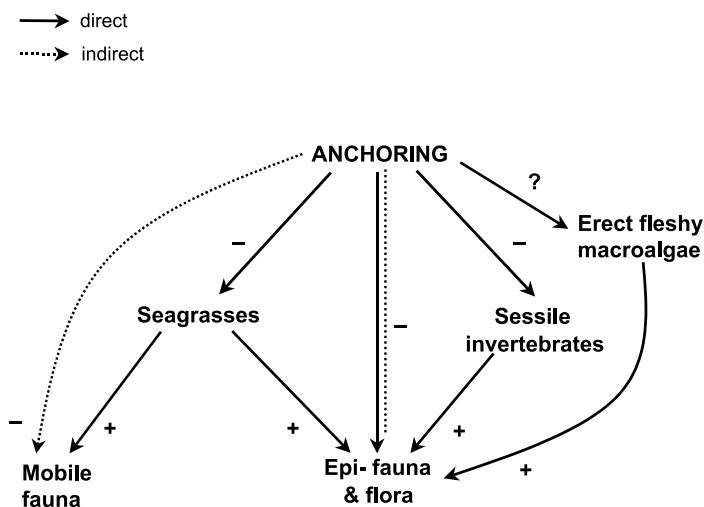


Fig. 1. Biological impacts of anchoring on benthic assemblages.

mainly *Posidonia oceanica* and *Cymodocea nodosa* meadows), and to a lesser extent the infralittoral algal assemblages (Table 1).

Many efforts assessed the consequences of anchoring on *P. oceanica* meadow, suggesting that this has a direct adverse effect on meadow cover and shoot density (García-Charton *et al.*, 1993; Francour, 1994; Poulain, 1996; Francour *et al.*, 1999). At present, no data are available on the threat caused by anchoring on the other Mediterranean assemblages.

Within MPAs or generally in highly frequented sites, different strategies have been implemented to reduce the impact of boat anchoring on corals and seagrasses. These include limiting boat number and size, anchoring prohibitions in certain periods of the year, or the deployment of mooring buoys of various shapes and types (see Poulain, 1996).

Table 1. Key-species and key-habitats potentially threatened by human recreational activities in the Mediterranean Sea.

Impact	Key-species	Key-habitat
Anchoring	<i>Posidonia oceanica</i>	<i>Posidonia oceanica</i> meadows
	<i>Cymodocea nodosa</i>	<i>Cymodocea nodosa</i> meadows
	<i>Cystoseira</i> spp.	Infralittoral algal assemblages
	<i>Cladocora caespitosa</i>	–
Scuba-diving	<i>Paramuricea clavata</i>	Coralligenous assemblage
	<i>Eunicella</i> spp.	
	<i>Lophogorgia ceratophyta</i>	
	<i>Pentapora fascialis</i>	
	<i>Astroides calycularis</i>	Sciaphilous assemblages
	<i>Leptopsammia pruvoti</i>	of marine caves
	<i>Parazoanthus axinellae</i>	
	<i>Myriapora truncata</i>	
	<i>Sertella</i> spp.	
	<i>Corallium rubrum</i>	
	<i>Paramuricea clavata</i>	Coralligenous assemblage
	<i>Eunicella</i> spp.	
	<i>Lophogorgia ceratophyta</i>	
	<i>Pentapora fascialis</i>	
Trampling	<i>Lithophyllum</i> spp.	<i>Lithophyllum</i> rims
	<i>Cystoseira</i> spp.	Rocky lower midlittoral
	<i>Patella</i> spp.	Rocky upper infralittoral
	<i>Dendropoma petraeum</i>	Vermetid reefs
	Small interstitial invertebrates	Sandy beaches of lower midlittoral and upper infralittoral

Recreational Scuba-diving and its impact on natural communities

Until recently, diving in protected areas was generally considered a non-destructive activity from which local communities and MPA managing bodies could gain benefit without inflicting damage. This may well have been the case before the rise in popularity of diving over the last twenty years.

New technology and the consequent safety improvements have greatly boosted the number of recreational divers (see Davis & Tisdell, 1995), giving rise to widespread concern that diving tourism may contribute to altering marine communities (Fig. 2) (Hawkins & Roberts, 1992). Scuba divers may affect the environment and living organisms in several ways, both intentionally and accidentally (e. g. through direct contact, air bubbles, or simply by their presence) (Talge, 1990).

Recent studies on the impact of diving activities on tropical reefs revealed that, as a result of educational campaigns, most divers caused little detectable damage to corals. When damage was detected it was most commonly in the form of unintentional contact, thus suggesting that buoyancy control is critical in minimising impacts on corals (Medio *et al.*, 1997).

Moreover, some authors have found that the impact of divers was not related to dive site topography, but may vary among diverse morphological types of benthic organisms (Rouphael & Inglis, 1997). In the Mediterranean Sea, smooth-bodied animals probably suffer less damage from frequent diver visits than hard sessile invertebrates (such as red corals, gorgonians and bryozoans) or coralline algae.

Using the erect foliaceous bryozoan *Pentapora fascialis* as an indicator of diver impact in a Mediterranean coralligenous community, some authors showed that both the size and density of *P. fascialis* colonies are greater within unfrequented sites than frequented ones (Sala *et al.*, 1996). However, the potential for causing significant dis-

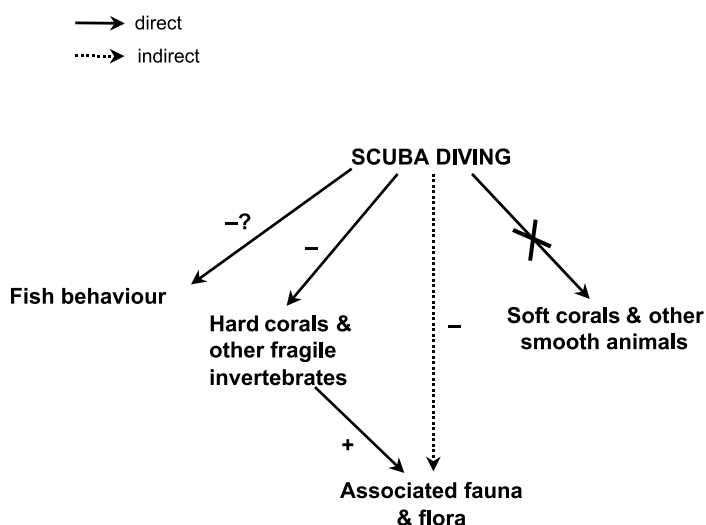


Fig. 2. Effects of recreational SCUBA-diving on natural communities.

turbance to Mediterranean subtidal areas has seldom been verified (Francour & Koukouras, 2000; but see Table 1).

The risk of long-term environmental degradation at the local scale as a result of diving activity is becoming increasingly well known (Davis & Tisdell, 1995). For this reason, many studies recommend implementing limits on diver numbers at popular sites in order to curb the impact (Hawkins & Roberts, 1993a). This problem can be tackled in two ways: (i) by increasing the number of dive sites in order to ‘dilute’ the concentration of divers in popular areas, or (ii) by reducing the amount of damage in a particular area by improving diver behaviour.

Research is also required to determine the rate at which damage occurs and how quickly recovery takes place. Effective management solutions should then be proposed on the basis of such research findings.

Effects of human trampling on the marine environment

Recreational activities have long been deemed to have an impact in terrestrial vegetated habitats (see review by Sun & Walsh, 1998). Only recently marine scientists have become aware of the detrimental effects of ‘foot traffic’ in the marine counterpart (Woodland & Hooper, 1977; Beauchamp & Gowing, 1982) (Fig. 3).

Marine organisms (i. e. sessile invertebrates, seagrasses, and erect macroalgae) revealed a high susceptibility to human trampling (people walking over intertidal and upper infralittoral areas) in a wide array of environmental conditions and habitats such as temperate rocky shores (Brosnan & Crumrine, 1994), coral reefs (Hawkins & Roberts, 1993b), saltmarshes and soft bottoms (Chandrasekara & Frid, 1996; Wynberg & Branch, 1997).

Rocky shallow areas submitted to intense trampling generally showed lower densities and diversities of algae than low-impacted areas (Addessi, 1994). Mechanical pressure

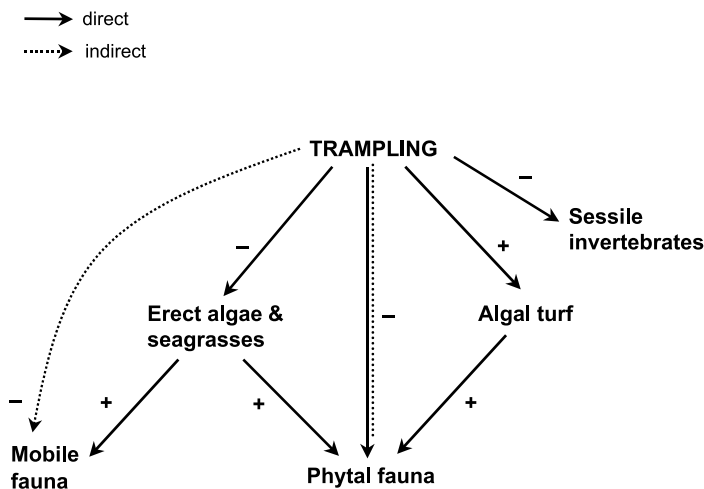


Fig. 3. Direct and indirect consequences of human trampling on the marine environment.

on erect algae may cause a rapid decrease in algal cover, canopy and biomass, leading the community to a simpler structural state dominated by low profile and turfing-form algae (Brosnan & Crumrine, 1994; Schiel & Taylor, 1999). The impact of different simulated people's steps was assessed on a brown seaweed, a coralline algal mat and bare rock, suggesting that the consequences of human disturbance on these habitats differed from one another. A great vulnerability of the macroalga was evident at both low and high intensities of usage. In contrast, coralline algae were significantly affected only by trampling at high intensity. Obviously, there was no evident effect of trampling on bare rock (Schiel & Taylor, 1999).

In tropical areas there is evidence that the immediate effects of trampling on corals may be variable (Liddle & Kay, 1987), being affected by the morphology and nature of marine organisms (i. e. high vs. low structural complexity, or, hard vs. soft skeletons) (Liddle, 1991). Meanwhile, the recovery rate of the disturbed populations appears to be related to species biology and to the environment in which they thrive (Liddle & Kay, 1987).

The characteristics of the substrate may also affect the outcome and the extent of pedestrian traffic disturbance. On an intertidal sand flat, very soft sediments were more susceptible than more compact substrates (Wynberg & Branch, 1997). In a recent study in the Puerto Rico coast, human trampling led to greater losses in rhizome biomasses in soft versus firmer substrates (Eckrich & Holmquist, 2000).

Trampling affects the fauna associated with marine algae and seagrasses both directly and indirectly. Human disturbance lowered densities and cover of sessile invertebrates (Povey & Keough, 1991; Brosnan & Crumrine, 1994; Eckrich & Holmquist, 2000).

Contradictory results emerged when examining the indirect effects of trampling (i. e. loss of structural complexity) on mobile fauna (Eckrich & Holmquist, 2000). After 4 months of experimental trampling, grass-shrimp densities were significantly lower in trampled plots than non-trampled controls. Conversely, the epibenthic fish community was apparently less sensitive to the decreased structural complexity of seagrass after human trampling.

In the Mediterranean Sea, presently no experimental study has been designed to identify the effects human trampling on marine communities (Milazzo & Ramos, 2000). Table 1 summarises the species and habitats potentially threatened by this activity here.

The greater interest and appreciation of coastal areas – indicated by an increasing number of people using them (Badalamenti *et al.*, 2000) – may, when unregulated, strongly alter shallow marine communities. In some over-frequented areas, this problem has been overcome by constructing raised boardwalks to concentrate human activity and thus limit the trampling of surrounding areas (Carlson & Godfrey, 1989; Liddle, 1991). Nevertheless, boardwalks themselves can negatively affect benthic assemblages at a local scale (Kelaher *et al.*, 1998a; b).

Other issues

Other potential threats linkable to recreational activities in MPAs include the feeding of fish by the public (Cole, 1994; Sweatman, 1996) and the social impact of tourism on the resident communities (Badalamenti *et al.*, 2000).

- *Fish feeding*

Similarly to terrestrial parks (Manski *et al.*, 1981; Manski, 1982), fish feeding by tourists (divers and snorkellers) is gaining popularity in both tropical and temperate MPAs (Cole, 1994; Sweatman, 1996). At present, however, potential changes in fish behaviour and spatial distribution caused by feeding activity are characterised by poor scientific documentation (Strong *et al.*, 1992; Cole, 1994; Sweatman, 1996).

- *Social impact*

Especially in those MPAs located in isolated places (i. e. small islands) and in southern areas (i. e. depressed zones), tourism may offer a broad range of opportunities to increase and supplement fishermen communities income (i. e. by boat tours, fishing trips, accommodations, and meals) (Badalamenti *et al.*, 2000). This may cause, particularly in young generations, a loss of traditional jobs in favour of the new economic activities and jobs generated by tourism. This makes it very important to tackle this issue from a socio-economic point of view. Increased research can help prevent the loss of the social and traditional value of a particular area.

Conservation and management in Mediterranean MPAs: which direction should we take?

At present, the scarcity of data on human impacts in Mediterranean MPAs makes a comparative discussion with those of other areas very difficult and inconclusive. This gap in our knowledge merits further discussion. First of all, there is a time delay due to the very recent history of Mediterranean MPAs compared with those created in tropical areas, where the extent of the impact of human recreation is wider and better recognised (Davis & Tisdell, 1996). Moreover, the limited knowledge on the biology and ecology of most Mediterranean marine organisms is probably a major constraint in detecting the consequences of visitor frequentation in marine habitats (Milazzo & Ramos, 2000).

To respond to the obvious needs of Mediterranean MPA managers, future research should be aimed at monitoring and detecting the effect and scale of the human pressure on marine community structure. As a result, a strong effort to single out the threatened species – implementing field experiments before and after impact (the recovery of disturbed populations) at an ample range of intensities – are strongly recommended (Milazzo & Ramos, 2000).

In the Mediterranean Sea, however, the wide array of differences – both environmental (e. g. geology, geomorphology, topography, hydrology, hydrodynamics, heterogeneity, trophism) and human use-related (e. g. typology, intensity, and time of usage) – make it difficult to find two similar MPAs. For this reason a specific plan for managing tourism use in each MPA should be designed, considering that each of the above mentioned factors may influence the susceptibility of marine organisms to human disturbance. This should provide a strategic tool for future management that could, for example, take into account the cumulative impacts of tourism use at a local scale.

These strategies should be implemented through education, training, and changes in legislation and policy, or providing visitors suitable alternatives of low-impact recreation (Fig. 4). However, although the role of education and training in managing the human impacts of recreational activities is theoretically effective in most of the non-Mediterranean MPAs, information on how it can be implemented appears to be missing.

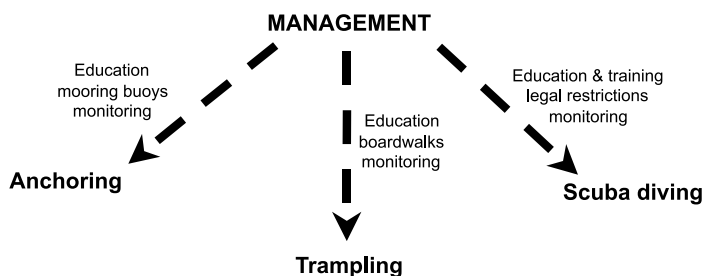


Fig. 4. Potential management tools to limit the impact of human recreational activities in MPAs.

Conclusions

The available studies on the effects of human recreational activities on marine communities demonstrate that the most common recreational and tourist activities in MPAs (i. e. trampling, anchoring, and SCUBA-diving), when intensive, can strongly modify marine communities at a local scale.

The evidence that ‘marine-based’ tourism and human recreational activities use are increasing in Mediterranean MPAs, but that the amount of research on their effects is still scarce, highlights a strong need for substantial research efforts.

Based on the information reviewed, we suggest the following topics as priorities for future research on the effects of visitor frequentation in Mediterranean MPAs: (1) assess the main marine habitats that potentially attract recreational use; (2) quantify the major cause-effect relationships between the biological impact and the amount of use for different recreational activities within MPAs; and, whenever possible, (3) accurately predict the scale (spatial and/or temporal) of a certain impact to help make responsible management decisions.

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